THE ELEMENTS

VOL. II.

THE OCEAN AND ATMOSPHERE.

VOL. II.

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THE ELEMENTS.

AN INVESTIGATION OF THE FORCES WHICH DETERMINE THE POSITION AND MOVEMENTS OF THE OCEAN AND ATMOSPHERE.

BY

WILLIAM LEIGHTON JORDAN.

VOLUME II.

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TO

SWINFEN JORDAN, ESQ.

This Volume is Dedicated,

AS A TRIBUTE OF AFFECTION AND ESTEEM,

BY HIS SON,

THE AUTHOR.

PREFACE.

Sir Isaac Newton, in the preface to his 'Principia,' remarks that—'all the difficulty of philosophy seems to consist in this—from the phenomena of motions to investigate the forces of nature, and then from these forces to demonstrate the other phenomena.' And then, after stating that on this principle he had, in the work above mentioned, demonstrated the motion of the heavenly bodies, he goes on to say: 'I wish we could derive the rest of the phenomena of nature by the same kind of reasoning from mechanical principles; for I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards each other, and cohere in regular figures, or are repelled and recede from

each other: which forces, being unknown, philosophers have hitherto attempted the search of nature in vain; but I hope the principles here laid down will afford some light either to that or some truer method of philosophy.'

The progress of knowledge appears to be gradually demonstrating the correctness of the opinion expressed in these sentences; and their appearance as a prefix to this volume will not be considered inappropriate, if I am not mistaken in supposing that herein is shown the mechanism which causes the stormy epochs in the northern and southern hemispheres respectively; the mechanical cause of the annual and diurnal oscillations of the barometer; the mechanical cause of the relative distribution of land and water in the northern and southern hemispheres; and the mechanical cause of certain marked peculiarities in the conformation of the undulations and fractures of the stratified surface of the earth. I offer no further comment on them; but—continuing in the words of Sir Isaac Newton—'I heartily beg that what I have here done may

be read with candour; and that the defects I have been guilty of upon this difficult subject may be not so much reprehended as kindly supplied, and investigated by new endeavours of my readers.'

WM. LEIGHTON JORDAN.

GERRARD'S CROSS, BUCKS:
December 17, 1866.

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THE ELEMENTS.

CHAPTER IV.

And say—of God above, or man below,
What can we reason but from what we know?

161. According to the arguments contained in our preceding chapters, the power which raises the counter-tides is also the power which, by counteracting the gravitation of the planets towards the sun, maintains the equilibrium of the solar system.

We there rejected the tidal theory suggested by Laplace: and postponed an investigation of the comparative merits of the Newtonian definition of centrifugal force and the theory of counter-attraction, as unnecessary for our then purposes.

This counter-attraction, inasmuch as it is a force which tends to carry the bodies which compose the solar system away from the centre of that system, may itself, not improperly, be termed a centrifugal force. But, nevertheless, the intrinsic difference between the nature of a centrifugal force of counter-attraction proceeding from astral gravitation, and

the nature of centrifugal force as defined by Sir Isaac Newton, is perhaps greater and of more importance than may be at first sight apparent.

Descartes based his philosophy on the assumption that the orbs of heaven have a naturally inherent property of motion, by which they tend to move constantly in straight lines.

Hobbes reasserted this assumption, and from it deduced the now generally accepted theory of the axial rotation of the moon, which is, in fact, inseparable from the Cartesian theory of motion in right lines; for the denial of the axial rotation of the moon necessitates the rejection of Descartes' theory of motion in straight lines.

The great triumphs of Newton are independent of the acceptance or rejection of this corner-stone of Descartes' philosophy. He nevertheless, in a somewhat modified manner, accepted it; and this in a manner less truly philosophical than did Descartes. Newton assumed the motion of the earth to result from a push or impulse given in a straight line, from which it is constantly deflected by the force of gravitation drawing towards the sun. And this original push or impulse, which, in fact, becomes an inherent power in the earth, tending to carry it onwards in a straight line, is the force which, according to the Newtonian philosophy, counteracts the attraction proceeding from solar gravitation, and prevents the earth from being drawn towards the sun. According

to this view, not only do the centripetal and centrifugal forces act in opposition to each other, but they are also intrinsically different in their natures.

We have to consider what, in the movements of the ocean and the atmosphere, may be expected to be the most manifest difference between the effects which should result from the action of a centrifugal force of the nature described by Newton, and the effects of the force of counter-attraction suggested in our preceding chapters as proceeding from astral gravitation.

According to the former theory, the motion of the earth is constantly tending to carry it out of its orbit and is the centrifugal force which counteracts the centripetal force of solar gravitation. Whereas, according to the latter theory, the motion of the earth is naturally in its orbit, along which that motion tends smoothly to carry it, without any strain or tendency to cause it to swerve to the one side or the other; and it moves along in that orbit, evenly held between opposing forces of gravitation: the centripetal force of solar gravitation, which tends to consolidate the solar system, being counteracted by the force of astral gravitation surrounding it; and which, by tending to draw the particles which compose the solar system asunder, counteracts the centralising tendency of its own forces of gravitation.

162. If it be admitted that a centrifugal force, caused by the axial rotation of the earth, tends to

cause an accumulation of water in the equatorial regions, then, looking at the actual motion of the moon in its orbit round the earth, analogy leads us to infer that if on the surface of the moon there lay any considerable extent of water, then not only would there be, by the earth's power of gravitation, a tide raised on that part of the moon's surface turned towards the earth; but also—even without taking into consideration any possible nature of the force which counteracts the earth's attraction—there would be, by centrifugal force, a tide raised on the side of the moon remote from the earth. And this accumulation of water on the side of the moon remote from the earth would result from the action of centrifugal force in a manner precisely analogous to the manner in which the action of that force causes an accumulation of water about the equatorial regions of the earth. For, as in the axial rotation of the earth, the velocity of the different parts of the earth's surface are in proportion with the distance of the different parts of the surface from the axis of rotation, and centrifugal force tends to carry the water to those parts of the surface which, being most remote from the axis of rotation, move with the greatest velocity: so also would centrifugal force tend to carry any water on the surface of the moon towards those parts of the moon's surface which, in the orbital motion of the moon, are most remote from the axis round which the moon's orbit is

described, and are, therefore, in that orbital motion, moved with the greatest velocity.

Now, looking at Plates X. and XI. in vol. i., and the remarks upon them on pages 98 to 101 of that same volume, it appears obvious that, according to what we have just stated, centrifugal force should tend to raise a tide on that part of the moon's surface which is turned away from the earth; for, in its orbital motion round the earth, that side of the moon moves with greater velocity than the side turned towards the earth.

163. When, however, we consider the orbital motion of the earth, as shown by those same plates, it appears obvious that on the surface of the earth the orbital motion of the earth cannot give rise to an action of centrifugal force analogous to that which results from the axial rotation of the earth, and which we have seen must also be brought into play by the orbital motion of the moon if any fluid lay on the surface of the latter: for all points of the earth are, in its orbital motion, moved with the same velocity. Not, as is the case in the axial rotation of the earth, and in the orbital motion of the moon, all swinging round the same axis; but each point moving round a different centre, and all parts of the earth moving evenly with the same velocity. And, therefore, the orbital motion of the earth cannot cause any effects analogous to those which result from that action of centrifugal force which

tends to move a fluid towards those parts of any body which, being most remote from any axis of rotation, move with the greatest velocity.

164. It will be observed that we here simply maintain that the orbital motion of the earth cannot give rise to a centrifugal force analogous to that which results from the axial rotation of the earth. And if, as we have remarked in section 15 in vol. i., by any possible mode of action—such as an innate and constant tendency of the earth to fly off at a tangent from its orbit—centrifugal force be the power which counteracts the force of solar gravitation, then must the counter-tides raised by that force be, of necessity, so nearly similar to such as would result from the action of counter-attraction proceeding from astral gravitation, that we must look elsewhere for such facts as may determine which of these forces it is that maintains the equilibrium of the solar system.

165. We there also suggested that, if the position of the earth and the direction of its motions be entirely controlled by gravitation—discarding centrifugal force, which is rendered requisite solely by the assumption that the earth moves by virtue of an innate tendency to motion in a straight line, or from the effect of a primary impulse given in a straight line—if, as we have just said, the position and motion of the earth be determined by gravitation, then there should be a tendency to the formation

of an annual tide alternately ebbing and flowing between the northern and southern hemispheres at the periods stated in section 15 of vol. i.

Since, however, the more marked of the phenomena which should result from the action of such a tide have by high authority been otherwise accounted for, and the existence of such a tide necessitates the rejection of theories which have been received with a confidence which amounts to a conviction of their correctness: we will first consider whether or not any effects which should manifestly result from the action of such a tide have been observed, and, remaining hitherto unaccounted for, have found a place in the records of ascertained facts. But this is a point which, from the great complication of forces in play, is more intricate than might at first sight be supposed; and we will therefore, whilst proceeding with it, make a general survey of ascertained facts, and briefly consider to what extent the effects of the forces which we have in our preceding chapters partially discussed are apparent in the actual movements of the ocean and the atmosphere. For this purpose, we will select such recorded facts as appear most suited, by means of an analysis of the causes from which they proceed, to elucidate the action of those forces.

CHAPTER V.

166. Major Rennell, on p. 18 of his 'Investigation of the Currents of the Atlantic Ocean,' referring to the current which has generally been found running northwards through Bhering's Straits, from the Pacific into the Arctic Ocean, remarks that, respecting this current, "we have no certain knowledge but during the height of summer. The report of Kobelef, quoted by Captain Burney, says that 'after the month of August the current changes and runs to the south (that is from the Polar sea into the Pacific), bringing with it the floating ice.' Such a change, and at that particular season, appears to be a very extraordinary fact; and to rest on a single authority." Now, let us consider what, according to our theory, should be the currents of Bhering's Straits.

167. In the first place, there is the annual tide referred to in chapter i. section 15, which in the northern hemisphere is at its highest point at the September equinox, and at its lowest point at the March equinox. And this tide should obviously tend to cause tidal currents to run through Bhering's Straits in opposite directions at different seasons of the year.

During spring and summer—that is, from the March to the September equinox—the tidal current resulting from this tide should tend to flow northwards through Bhering's Straits; and during autumn and winter—that is, from the September to the March equinox—the tidal currents resulting from this tide should tend to ebb southwards through those straits.

Now, if there were no counteracting forces in play, and if the tidal currents resulting from this tide obey the same laws as do those resulting from the diurnal tides, then the northward current through the straits should tend to run at its strongest about the end of June, and the southward current should tend to run at its strongest about the end of December. And we shall find that the influence of the oscillations in latitude of the culminating points of the solar tides will tend to cause the northward current to run strongest some time before the June solstice, and to make the southward current run strongest some time after the December solstice. For, in the former case the solar tide, and in the latter case the counter-solar tide, will be acting in conjunction with the annual tide.

Let us consider the alternate oppositions and conjunctions of the annual tide, and the oscillations in latitude of the culminating points of the diurnal tides. We will first, setting aside for the present the oscillations in latitude of the lunar tides, take the oscillations in latitude of the solar tides alone into consideration. With the oscillations in longitude, which

cause the diurnal rising and falling, we are not at present concerned.

168. When the sun is on the equator, then the culminating points, both of the solar and of the counter-solar tide, are also at the equator. But as the sun diverges from the equator, either northwards or southwards, the culminating point of the solar tide diverges with it, whilst the culminating point of the counter-solar tide diverges equally in the opposite direction. And thus there is caused an oscillation of water twice a year from the equator towards the poles, and back twice a year from the poles towards the equator. So that the highest point of this oscillation is at the equator during each of the equinoxes, and at its lowest at the equator during each of the solstices, being, therefore, beyond the tropics at its lowest point during each of the equinoxes, and at its highest point during each of the solstices.

That is, after each equinox the solar tides commence to diverge from the equator, and culminate, the solar tide in the one hemisphere and the counter-solar tide in the other hemisphere, at each of the solstices. And then, after each of the solstices, they commence to converge towards the equator: the one flowing towards the equator from the tropic of Cancer, and the other from the tropic of Capricorn.

169. And therefore, from the March equinox to the June solstice, the solar tide acts in conjunction with the flow of the annual tide, in the northern

hemisphere; and from the September equinox to the December solstice it acts in conjunction with the flow of the annual tide in the southern hemisphere.

After each of the solstices the solar tide ceases to act in conjunction with the annual tide, but turns to flow back towards the equator, separating from its conjunction with the direction of the annual tide, which latter changes its direction at the equinoxes.

At the September equinox the solar tides are at the equator, and the annual tide at its culminating point in the northern hemisphere; and immediately after the September equinox, the annual tide tends to fall southwards, the counter-solar tide at the same time falling northwards from the equator. So that in the northern hemisphere at that period these two tides are suddenly brought into opposition: the one rushing southwards towards the equator, and the other rushing northwards from the equator.

At the March equinox the solar tides are again at the equator, but the annual tide is then at its culminating point in the southern hemisphere; and immediately after the March equinox the annual tide tends to fall northwards, the counter-solar tide at the same time turning southwards from the equator. So that in the southern hemisphere at that period these two tides are suddenly brought into opposition: the one rushing northwards towards the equator, and the other rushing southwards from the equator.

170. Therefore, at the September equinox, when the

annual tide tends to fall southwards from the northern hemisphere, it meets the counter-solar tide flowing northwards from the equator. And at the March equinox, when the annual tide tends to fall northwards from the southern hemisphere, it meets the counter-solar tide flowing southwards from the equator. There is in each of these cases a sudden conflict of forces; which, at the September equinox occurs in the northern hemisphere, and at the March equinox in the southern hemisphere.

171. But besides these equinoctial conflicts which occur when the annual tide tends to fall from its extreme culmination in either hemisphere, that tide also comes into conflict with the solar tide at each of the solstices. For the annual tide is crossing the equator at each of the solstices: passing northwards at the time of the June solstice, and southwards at the time of the December solstice. And therefore, as the solar tide turns southwards in the northern hemisphere at the period of the June solstice, it then comes into conflict with the annual tide in that hemisphere. And as it turns northwards in the southern hemisphere at the period of the December solstice, it then comes into conflict with the annual tide in that hemisphere.

172. Thus four times each year the annual tide is suddenly brought into conflict with the solar tides, that is to say, twice with the solar and twice with the counter-solar tide. The solstitial conflicts are

both with the solar tide, and occur as the annual tide crosses the equator, that is, when it is half-way between the extremes of its oscillation. But the equinoctial conflicts occur at the turning points of the annual tide, that is, when it commences to fall from its extreme culmination; and, in the northern hemisphere, comes into conflict with the counter-solar tide in September, and, in the southern hemisphere, comes into conflict with the solar tide in March.

Thus these conflicts occur in the northern hemisphere at the time of the September equinox and at the time of the June solstice; and in the southern hemisphere they occur at the time of the March equinox and at the time of the December solstice.

173. In these conflicts, as the axial rotation of the earth causes the tides setting from the equator to tend eastwards, and those setting towards the equator to tend westwards, they form at the points of conflict revolving fragments whose eastern sides whirl from the equator and western sides towards the equator. The opposing forces thus whirl in conflict as they cross, and then pass onwards each upon its course.

174. Oceanic conflicts of this nature have not been subjects of practical investigation. But their atmospheric counterparts are clearly such as the able investigations of Reid, Piddington, Dove, and others, have shown to be the nature of such storms as are known under the various names of Hurricanes, Cyclones or Typhoons. These storms form a matter

of detail which does not concern us at present, excepting in as far as the importance of the tidal forces which we have been considering is shown by the relative number of storms which occur in each hemisphere at the periods at which these tidal forces come into conflict.

From Alexander Keith Johnston's Physical Atlas we extract the table placed on the opposite page, giving a list of recorded storms in different parts of the world; from which it will be seen that the occurrence of these storms, in each hemisphere, shows a marked accordance with the periods of conflict which we have above deduced from theory. The coincidence of the stormy periods, as shown by this table, in each hemisphere, with the periods of conflict which we have described, appears clearly to show the effects and the importance of the annual tide. These stormy periods are phenomena which should manifestly result from the action of such a tide, and, remaining hitherto unaccounted for, they have found a place in the records of ascertained facts.

175. If, however, there were no counteracting forces in play, then the periods of conflict should be precisely the same each year; for the turning point of the annual tide, if not interfered with by other forces, would always occur exactly at each of the equinoxes. As also the solar tides, if not interfered with by other forces, would commence to diverge from the equator at each of the equinoxes, and commence to

TABLE OF STORMS RECORDED IN VARIOUS LOCALITIES IN EACH MONTH OF THE YEAR.

No. of years of observation.	Locality.	Months.											
		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
354	West Indies	. .	1	2	. .	. .	4	15	36	25	27	1	2
64	China Sea	. .	. .	. .	. .	. .	2	5	5	18	10	6	. .
46	Bay of Bengal	1	. .	1	1	7	3	. .	1	. .	7	6	3
39	South Indian Ocean	9	13	10	8	4	. .	. .	. .	1	1	4	3
24	Mauritius	9	15	15	8	. .	. .	. .	. .	. .	. .	. .	6

converge towards the equator at each of the solstices. As far as the oscillations of the solar tides are concerned, the ebbing and flowing of the annual tide would each year be similar, as regards both the amount of its rise and fall, and the periods of the year at which its alternate ebbing and flowing in each hemisphere occurs.

176. Let us, however, now consider the oscillations in latitude of the lunar tides.

When the moon is on the equator, then the culminating points of the lunar tides are also at the equator; but as the moon diverges from the equator, the lunar and counter-lunar tides diverge equally in opposite directions, in the same manner as do the analogous solar tides. And, as similar positions of the moon in its orbit round the earth do not recur in each succeeding year at similar periods of the year, the influence of this oscillation of the lunar tides, in increasing or lessening the height, as well as in retarding or accelerating the ebbing or flowing of the annual tide, will vary from year to year.

177. And since the plane in which the moon moves in its orbit round the earth is inclined to the ecliptic, and the points at which it crosses the ecliptic are constantly changing:—therefore the extremes of the moon's declination from the equator must vary in each lunation in accordance with the change in the position of the points at which it crosses the ecliptic. And as these points, or nodes, regress on

the ecliptic at a mean rate of 19° 19′ 42·316″ a year; they will therefore recur to similar points of the ecliptic in cycles of about 18·6 years. But, as the plane of the ecliptic is inclined to the earth's equator, the cycle in which a similar series of amounts of lunar declination from the equator recurs will be that in which similar nodes recur at similar points of the ecliptic at similar periods of the year. And, as the nodes make eight complete revolutions in 149 years with approximate accuracy; therefore the tidal influence resulting from variations of lunar declination, will recur approximately in cycles of 149 years. That is to say; since the nodes regress at the average rate of 19° 19′ 42·316″ a year, they therefore in 149 years regress 2879° 56′ 5.084″; which differs less than 4′ from 2880°, or 8 complete revolutions. And we may therefore, as far as our present purposes are concerned, regard this as a recurring cycle.

And, since the angle at which the plane of the moon's motion in its orbit round the earth is inclined to the plane of the earth's motion in its orbit round the sun is about 5°; and the angle at which the plane of the earth's motion in its orbit round the sun is inclined to the plane of the earth's axial rotation is about $23\frac{1}{2}$°; therefore—in consequence of the changing of the points of intersection of these planes, before mentioned—the oscillations of the moon in latitude extend, during some parts of the cycle of 149 years, to more than 28° from the equator on each side;

and are during other parts of that cycle confined within 18° from the equator.

178. It may here be observed that even if this cycle of 149 years were absolutely exact, which it is not, it would not suffice to determine a precise recurrence of lunar influence as far as the recurrence of storms in particular localities is concerned. Because for such a purpose we should have to take into consideration the oscillations in longitude, which cause the diurnal tides; which is a matter of detail which does not concern us at present. We have for the present to deal solely with oscillations in latitude: and for this purpose the cycle of 149 years is sufficiently precise: if at any solstice the greatest possible amount of lunar declination from the equator occur, then a similar extreme of declination will recur after a period of 149 years. We will not at present investigate the intermediate cycles in which similar positions recur approximately: but will first consider how the moon's different positions in declination in each revolution round the earth will affect the annual tide, and the solar tides.

It will, however, be observed that as far as the forces which we have hitherto investigated are concerned; if at any period of the year the combined action of those forces cause the occurrence of storms at any particular localities on the earth's surface: then, if at the same period in any other year, the moon be twenty-four hours distant from the position

which it occupied in its orbit at the former period, there may be a nearer approach to a similar recurrence of storms than if there were only twelve hours' difference in the position of the moon. For, in the former case there will be a recurrence of a similar influence of the forces resulting from the orbital motion of the earth, whereas in the latter case the action of these forces would be completely reversed. With a difference of twenty-four hours in the position of the moon, storms might recur in similar localities approximately; which storms, if a change of only twelve hours in the moon's position had occurred, instead of a change of twenty-four hours, might not have recurred in the same localities at all. That is to say; an Atlantic storm which, at the end of a cycle of years, might recur in the Atlantic with approximate similarity in case of there being a difference of twenty-four hours in the position of the moon; might not, if that difference of the moon's position were only twelve hours at the end of the cycle, recur in the Atlantic at all, but be transferred to the Pacific. For there would in such case be in the Pacific a nearer approximation than in the Atlantic, to the recurrence of a combination of forces similar to that which had been the cause of the Atlantic storm.

179. The moon on an average oscillates backwards and forwards between the northern and southern hemispheres in 27·212 days. And therefore in that period each of the lunar tides acts alternately in con-

junction with and in opposition to the annual tide: also being alternately in conjunction with and in opposition to each of the solar tides in that same period. And when at any of the periods of conflict which we have described between the annual tide and the solar tides, the lunar tides act in conjunction with either of the opposing forces, then the conflict will be intensified; whereas at other times the influence of the lunar tides will be such as to cause a gradual coalescence and crossing instead of a sudden conflict between those forces.

And, not only will the lunar tides thus tend at times to diminish and at other times to increase the intensity of those conflicts; but also, they will at times tend to retard and at other times to hasten their occurrence: causing them to take place sometimes before, and at other times after the solstitial and equinoctial periods at which they would otherwise recur with precision. And besides this, the lunar tides will themselves have periods of independent conflict with the annual tide; and also with the solar tides. Let us consider the manner in which their influence may act at the various epochs of conflict.

180. If at the September equinox the moon cross equator, in either direction, at the same time as the sun, it will tend to intensify the equinoctial conflicts in the northern hemisphere; or if at the March equinox it cross the equator, in either direction, at the same time as the sun, it will tend to intensify

the equinoctial conflict in the southern hemisphere. For in each case one or other of the lunar tides acts in conjunction with the counter-solar tide in its conflicts with the annual tide.

If at the September equinox the moon be at its farthest declination north or south : then in the former case the lunar and in the latter case the counter-lunar tide will, by acting in conjunction with the annual tide, intensify the conflict between that tide and the counter-solar tide in the northern hemisphere. And one or other of the lunar tides will at the same time come into conflict with the solar tide in the southern hemisphere.

If at the March equinox the moon be at its farthest declination either north or south: then in the former case the counter-lunar tide, and in the latter case the lunar tide will, by acting in conjunction with the annual tide, intensify the conflict between that tide and the counter-solar tide in the southern hemisphere. And one or other of the lunar tides will at the same time come into conflict with the solar tide in the northern hemisphere.

If at the June solstice the moon cross the equator, one or other of the lunar tides will act in conjunction with the annual tide in its conflict with the solar tide in the northern hemisphere: and the other of the lunar tides will at the same time come into conflict with the counter-solar tide in the southern hemisphere.

If at the December solstice the moon cross the equator, one or other of the lunar tides will act in conjunction with the annual tide in its conflict with the solar tide in the southern hemisphere: and the other of the lunar tides will at the same time come into conflict with the counter-solar tide in the northern hemisphere.

If at the June solstice the moon be in its farthest declination either north or south, then in the former case the lunar tide, and in the latter case the counter-lunar tide, will act in conjunction with the solar tide in its conflict with the annual tide in the northern hemisphere.

And if at the December solstice the moon be at its farthest declination north or south, then in the former case the counter-lunar tide, and in the latter case the lunar tide will act in conjunction with the solar tide in its conflict with the annual tide in the southern hemisphere.

The seven foregoing paragraphs show the various extremes of conjunction and opposition of the lunar tides and the annual and solar tides. The influence of the moon in causing oceanic tides is universally recognised. And the coincidence of periodically recurring currents in the ocean with the movements of the moon to and from the equator, has been pointed out by Humboldt and others. But the analogous influence of the moon on the atmosphere has not been so generally recognised. The con-

nection between the recurrence of atmospheric disturbances and the recurrence of similar positions of the moon is, however, maintained by Lieutenant Saxby, R.N. in his 'Weather System;' in which he states that from long continued observation he was led to combine lunar changes and actual weather disturbances into the relationship of cause and effect. We are, however, verging upon matters of detail, with which, though deeply interesting in themselves, we are not at present concerned.

181. We have seen that the effect of the solar tides upon the annual tide will be similar each year; but that the effect of the lunar tides will, in consequence of the gradual changing from year to year of the periods at which the extremes of lunar declination occur, sometimes retard and at other times hasten the period at which the annual tide turns. And that it will also, in cycles of 149 years, cause the rise of the annual tide to be higher during one part of that cycle of years than during another part of it: for eight times during that cycle of years the moon's oscillations in latitude are increasing in each successive revolution round the earth; and eight times, at intermediate periods, they are decreasing. During the years 1856, 1857, and 1858 each oscillation extended about 28° from the equator on each side; whereas, during the years 1865, 1866, 1867, and 1868 they extend only about 19° from the equator on each side. These oscillations at times

extend 29°, and at other times only 17° from the equator; and, as they are accomplished in periods of about 27¼ days, therefore the moon during some parts of the cycle of 149 years, changes its latitude at the rate of 4¼° each day, and at other periods at the rate of only 2½° each day. And also during some portions of that cycle its influence will cause the tidal current to set southwards through Bhering's Straits before the arrival of the September equinox; and during other portions of that cycle it will retard the time at which its southward ebbing commences until after the September equinox. Any tidal current running through those straits at one period of the year must be balanced by an equal current running in the opposite direction at some other period of the year. And therefore our theory requires that there should be a current running southwards through those straits at some period of the year. And the current reported by Kobelef, which Major Rennell, in the quotation on which we are commenting, mentions doubtfully, accords with that theory. And also, the period of its occurrence, as reported by Kobelef—namely, 'after the month of August'—is by no means at variance with our theory, for, as we have shown, it should in accordance with that theory during some years turn southwards some time before, and during other years some time after the September equinox.

CHAPTER VI.

182. From the foregoing chapter it appears that the rise and fall of the annual tide must, by the complications caused by the oscillations in latitude of the culminating points of the solar and lunar tides, be in a great measure concealed from superficial observation. And that, therefore, the only observable effects, which we can expect to find apparent as far as regards the actual difference in the height of the water, is the difference in the heights of the equinoctial tides mentioned in section 15; and also, owing to the variation in the effects of lunar declination, this difference will only be observable in the average of an extended series of years. And, besides this, a vast volume of water might indeed oscillate backwards and forwards between the northern and southern hemispheres without making any apparent changes in the height of the water along the coast lines. For the vis inertiæ tide is, in fact, raised by the pressure of the currents against the banks of the ocean, and therefore the tendency of such a tide is to cause the level of the water to be higher along the shores than in the central parts of the ocean; and the waters of the

attraction tide must restore the general level of the ocean before raising the level along the shores. We must, however, from the greater average height of the attraction tide, and the oscillations in longitude of its highest point, expect to find that in the records of disasters caused at seaports by unusually high tides, such disasters will, in the northern hemisphere, have occurred more frequently about the time of the September than the March equinox; and in the southern hemisphere more frequently about the time of the March than the September equinox. We cannot, for the present, do more than compare the equinoctial periods in the two hemispheres, because, as far as the arguments which we have hitherto adduced are concerned, we have no ground for determining what relation the tidal forces which cause the annual tide bear to those which cause the lunar and the solar tides.

183. It will, however, be observed that, when the annual tide, raised by attraction, is in the one hemisphere, then the concomitant vis inertiæ tide is in the opposite hemisphere, and that, therefore, though the actual difference in the height of the water in the two hemispheres is only the difference between the relative height of those two tides, there is nevertheless an intrinsic difference in the nature of those tides; and this difference we may, not unreasonably, expect to find more or less apparent in both the ocean and the atmosphere.

184. We have remarked, in section 143, that

when an atmospheric tide is raised by attraction, the force which raises the tide tends to prevent atmospheric pressure downwards; so that the increase in the depth of the atmosphere will not cause an equivalent rise in the height of the barometer. But, in the case of such atmospheric tides as result from vis inertiæ, we must obviously expect to find that the pressure of the current, by which the tide is raised, will cause a rise of the barometer more or less equivalent to the height of the tide raised by the force of vis inertiæ.

This being the case, and if the earth's position and movements be determined by gravitation, then we must expect that the action of these tidal forces will be marked by the barometer showing less atmospheric pressure on those parts of the earth's surface which may be turned in the direction in which it may be moving than on the opposite parts of the surface. And, in fact, Captain Maury, in the diagram of the winds at the end of his 'Physical Geography of the Sea,' marks the atmospheric pressure at 28·93 about the Antarctic circle, and at 29·76 about the Arctic circle. This difference of pressure being obviously such as, according to our theory, we should expect if the solar system be moving in the direction of the south pole.

But also; for the same reasons which cause a greater pressure in the northern than in the southern hemisphere in case of the earth being in motion

in the direction of the south pole; reasoning from analogy we must expect to find that, all other circumstances being equal, the barometer will be lower on that part of the earth's surface which may be turned in the direction in which the earth moves in its orbit than at the opposite point of the surface. And as at the September equinox the point of sunrise on the tropic of Cancer is in advance; and at the March equinox the point of sunrise on the tropic of Capricorn: these forces should, in the northern hemisphere tend to cause a lower barometer at sunrise in September than at sunrise in March: and also a higher barometer at sunset in March than at sunset in September. The reverse of these effects occurring in the southern hemisphere.

That is to say, that, on the average, the barometer should, in the northern hemisphere show less atmospheric pressure in September than in March; whereas in the southern hemisphere it should show less atmospheric pressure in March than in September. And that recorded observations are such as we have thus deduced from theory, appears from the opposite table, which we extract from Dove's 'Law of Storms,' page 42, which gives, 'in decimals of an inch, the differences from the mean height of the barometer observed in the Atlantic ocean, from latitude 35° N. to 35° S.' The seasons marked in the table are those of the northern hemisphere, and consequently the table shows a clearly marked oscillation of the

ATMOSPHERIC PRESSURE IN THE TRADE WIND ZONE, ATLANTIC OCEAN.

Latitude.		Winter.	Spring.	Summer.	Autumn.
North	35°—30°	+ 0·192	+ 0·122	+ 0·171	+ 0·083
	30 —25	+ 0·173	+ 0·145	+ 0·134	+ 0·078
	25 —20	+ 0·067	+ 0·087	+ 0·050	— 0·002 **
	20 —15	+ 0·007 *	+ 0·008 ‡	— 0·048 ‖	— 0·049
	15 —10	— 0·062	— 0·042	— 0 103	— 0·093
	10 — 5	— 0·104	— 0·107	— 0·120	— 0·112
	5 — 0	— 0·119	— 0·133	— 0·121	— 0·093
South	0 — 5	— 0·117	— 0·111	— 0·087	— 0·069
	5 —10	— 0·072	— 0·076	— 0·056	— 0·024
	10 —15	— 0·033	— 0·029	— 0·004	+ 0·027
	15 —20	+ 0·007 †	+ 0·018 §	+ 0·045 ¶	+ 0·049 ††
	20 —25	+ 0·042	+ 0·050	+ 0·077	+ 0·124
	25 —30	+ 0·050	+ 0·050	+ 0·073	+ 0·085
	30 —36	— 0·030	+ 0·029	+ 0·028	+ 0·046
Mean height		30·020	30·025	30·057	30·039

* Higher than in Summer. † Lower than in Summer. ‡ Higher than in Autumn. § Lower than in Autumn.
‖ Lower than in Winter. ¶ Higher than in Winter. ** Lower than in Spring. †† Higher than in Spring.

barometer according with the oscillations of the earth in its orbital motion: the barometer falling in the northern hemisphere when that hemisphere is in advance in the earth's orbital motion, and at the same time rising in the southern hemisphere: and in like manner, falling in the southern hemisphere when that hemisphere is in advance in the earth's orbital motion, and at the same time rising in the northern hemisphere. This, it will be observed, is an ascertained phenomenon which is clearly in accordance with what theory would lead us to expect under the action of the forces which cause the annual tide and its concomitant counter-tide. The force of attraction, which draws the greater mass of air into the hemisphere which is in advance, tends to prevent atmospheric pressure downwards, and therefore causes a low barometer: whereas the pressure of the vis inertiæ currents causes a high barometer in the opposite hemisphere.

185. Besides these annual variations we should also expect that, at least in the equatorial regions, the barometer should be lower on the average at sunrise than at sunset: for the line of sunrise on the surface of the earth is in advance as the earth moves in its orbit, and is therefore under the atmospheric tide raised by attraction; whereas the line of sunset is under the atmospheric tide caused by vis inertiæ, which tends to cause an increase of pressure on the barometer. From the diurnal oscillations of the barometer

we may judge approximately what relation the tidal forces at present under consideration bear to those proceeding from the sun and moon. And also the average difference in height at sunrise and sunset, compared with the average difference in height in the northern and southern hemispheres, should approximately show the relation which the velocity of the earth's motion in its orbit bears to the velocity of the motion of the solar system through space. For this purpose we should, however, require a more extended and more detailed series of observations than we at present possess: and we will therefore simply consider to what extent the clearly ascertained diurnal oscillations of the barometer corroborate the theory at present under consideration.

186. The diurnal oscillations of the barometer form one of its most marked phenomena. From Sir John Herschel's article on Meteorology in the Encyclopædia Britannica, we extract the following table which 'exhibits the amount of its daily fluctuations above and below the mean value, as deduced from the calculations of Kämtz.' The epochs of greatest pressure shown on the table are, according to the same authority, generally speaking, about 9 h. or 9¼ h. A.M. and 10½ h. or 10¾ h. P.M.; and the epochs of least pressure at 4 h. or 4¼ h. P.M. and 4 h. A.M. And therefore this table does not show the relative amounts of pressure at the hours of sunrise, sunset, mid-day and midnight; but at epochs intermediate between those epochs.

TABLE SHOWING THE DIURNAL OSCILLATIONS OF THE BAROMETER IN VARIOUS LOCALITIES.

Latitude.	Place.	Morning. Min.	Forenoon. Max.	Afternoon. Min.	Evening. Max.
0° 0′	Atlantic Ocean	− 0·056	+ 0·069	− 0·045	+ 0·045
0 0	Pacific Ocean	− 0·032	+ 0·040	− 0·045	+ 0·028
5 6 S.	Payta	+ 0·004	+ 0·051	− 0·082	+ 0·050
8 30 N.	Sierra Leone	− 0·022	+ 0·032	− 0·038	+ 0·031
10 28 N.	Cumana	− 0·022	+ 0·043	− 0·050	+ 0·037
10 36 N.	La Guayra	− 0·023	+ 0·054	− 0·048	+ 0·029
12 3 S.	Callao	− 0·038	+ 0·045	− 0·044	+ 0·035
12 3 S.	Lima	− 0·071	+ 0·065	− 0·067	+ 0·050
16 0 S.	Pacific Ocean	− 0·021	+ 0·040	− 0·040	+ 0·028
17 29 S.	Otaheite	− 0·035	+ 0·052	− 0·030	+ 0·018
18 0 N.	Pacific Ocean	− 0·020	+ 0·034	− 0·044	+ 0·027
22 35 N.	Calcutta	− 0·017	+ 0·052	− 0·038	+ 0·018
22 54 S.	Rio de Janeiro	− 0·036	+ 0·040	− 0·040	+ 0·030
30 2 N.	Cairo	− 0·008	+ 0·035	− 0·055	+ 0·030
45 24 N.	Padua	− 0·004	+ 0·012	− 0·014	+ 0·007
48 8 N.	Munich	− 0·011	+ 0·011	− 0·008	+ 0·009
51 29 N.	Halle	− 0·006	+ 0·013	− 0·012	+ 0·005
60 57 N.	Abo	− 0·009	+ 0·002	− 0·005	+ 0·008

Now, the fact of the barometer showing a less amount of atmospheric pressure in the southern than in the northern hemisphere, we have already mentioned as being in accordance with what we should expect in case of a motion of the solar system in the direction of the south pole, notwithstanding there being a greater mass of air over the southern than over the northern hemisphere, for the force of attraction which draws the air so as to form a tide in the southern hemisphere tends to prevent downward pressure upon the barometer; whereas the force of vis inertiæ which, by means of converging currents, forms a tide in the northern hemisphere, tends by the pressure of those converging currents to cause increased pressure upon the barometer.

And, the annual oscillation of pressure backwards and forwards between the northern and the southern hemispheres, which is shown by the table on p. 29, we mentioned as being in accordance with what we should expect from effects of attraction and vis inertiæ precisely analogous to the foregoing, seeing that the northern and southern hemispheres are alternately in advance in the orbital motion of the earth.

If such be the cause of the difference in atmospheric pressure in the northern and southern hemispheres; and of the annual oscillation of pressure between the two hemispheres: then the diurnal oscillation of pressure shown by the table opposite is precisely such as we should naturally expect under the action of the

opposing forces of solar and astral gravitation, provided that the general course of aerial currents be that which we have described in section 46.

For the forces of attraction just mentioned tend to raise aerial tides, and diminish atmospheric pressure on those parts of the earth's surface which may be turned in the direction of their influences respectively. And as, according to section 46, excepting the lower strata of air in each of the temperate zones, the general tendency of the whole mass of the atmosphere is westwards:—

Therefore, on that part of the earth's surface which lies east of the sun—that is to say, on that part of the surface which is moving from the point of noon to the point of sunset—the tidal action of the sun acts in conjunction with the aerial currents, drawing them towards it in the natural direction of their course, and therefore tending to diminish rather than to cause increase of pressure. Whereas, on that part of the earth's surface which lies west of the sun —moving from the point of sunrise to the point of noon—the tidal action of the sun acts in opposition to the general course of the aerial currents, dragging against and tending to retard them, and tending therefore to cause, by this opposing action of attraction and vis inertiæ forces, an increase of pressure upon the barometer between the hours of sunrise and noon.

And, in precisely the same manner as that in which

the tidal action of the sun, by acting alternately in opposition to, and in conjunction with the course of the currents which result from the axial rotation of the earth, causes an increase of atmospheric pressure between the hour of sunrise and noon, and a decrease of pressure between noon and the hour of sunset; so also, in a manner precisely analogous, must the tidal action proceeding from astral attraction tend to cause an increase of atmospheric pressure between the hour of sunset and midnight, and a decrease of pressure between midnight and the hour of sunrise. And also, from the more concentrated action of the solar force, the extremes of oscillation resulting from its action should be greater than those resulting from the action of astral gravitation: which is shown on the table by a greater extreme of rise and depression occurring in the day time, than occurs at night.

Since, as far as those diurnal oscillations of the barometer which we have under consideration are concerned, they result, in the temperate zones, from the upper currents of the atmosphere alternately pressing upon or being raised upwards from the lower strata; whereas within the tropics both the upper and the lower strata are similarly acted upon. Therefore we should expect to find those diurnal oscillations more regular and more clearly apparent in the tropical than in the temperate zones. And this appears to be in accordance with observed facts. For Sir John Herschel, referring to this diurnal

oscillation, in the article above alluded to, remarks that 'though in extra-tropical latitudes it is for the most part so overlaid by casual variations as not to be remarked in a single day. On the other hand, between the tropics, and especially in the equatorial regions, its regularity of progress is most striking. Thus, Colonel Sykes remarks that, among many thousand observations taken personally by himself on the plateau of the Deccan there was not a solitary instance in which the barometer was not higher at 9.10 A.M. than at sunrise, and lower at 4.5 P.M. than at 9.10 A.M. whatever the state of the weather, &c., might be.'

It will be observed that the action of the forces of solar and astral gravitation in causing these oscillations of pressure, is dependent on the course of the upper currents of the atmosphere being such as we described in section 46. And it appears to us that, if any further arguments beyond those given in vol. i. were requisite to show that those currents actually are such as we there described, then these diurnal oscillations of the barometer might not unreasonably be accepted as convincing proof that such is actually the course of those currents.

Halley, as quoted by Dove in his 'Law of Storms,' page 38, says that the 'north-east trade wind below will be attended with a south-westerly above, and the south-easterly with a north-westerly above.' And Dove also appears himself to be of the same

opinion. But this is absolutely at variance with the theory suggested in our preceding volume: according to which the westward pressure of that upper strata is the greatest wind-creating power in the atmosphere; and according to which, with the exception of comparatively trivial counter-currents, and the exterior limits of the trade winds where the air from the upper strata curves eastwards in descending into the lower strata; with these exceptions, the tendency of the whole mass of air in the equatorial regions is westwards:—that in the lower strata converging towards the equator, and that in the upper strata diverging from the equator. The exceptional direction taken periodically by the monsoons in the lower strata must necessarily result from the influence of change of latitude whenever the trade wind of one hemisphere is carried any considerable distance across the equator into the opposite hemisphere, and is therefore no argument against the wind-creating action of the westward pressure of the equatorial regions. Dove has ably shown, and we believe first suggested, that these monsoons are simply extensions of the trade winds. But this eastward sweep of the trade wind, which periodically forms the monsoons, must, according to our theory, be confined to the lower strata: the air above in the upper strata, with the trivial exceptions above mentioned, running constantly westwards.

CHAPTER VII.

187. Major Rennell, in page 15 of the work which we alluded to in chapter v. mentions that, according to the French observations in Egypt, the water at the eastern end of the Mediterranean was found to be much lower than the level of the Red Sea. And this he mentions as showing the great amount of evaporation which takes place in the former. But if the relative levels of these seas were determined by the relative amounts of evaporation in each, we should expect to find that the level of the Red Sea would be the lower of the two. For the temperature of that sea and the ocean adjacent to it must greatly exceed that of the Mediterranean and the adjacent parts of the Atlantic.

But, according to our theory, the westward pressure resulting from axial rotation would obviously tend to cause such a difference of level as has, according to Major Rennell's statement, been ascertained to exist. For in the Red Sea there must be a current tide permanently raised by the westward pressure from the Indian Ocean; whereas the eastern end of the Mediterranean is depressed by

the westward tendency of its waters. The average tendency of westward pressure is to depress the water on the eastern, and to raise it on the western, side of each ocean.

Excepting the influence of the contortions of the coast in causing eddies, the tendency of the westward pressure of the waters of the Mediterranean must tend to cause currents to run westwards in the southern parts of that sea, and eastwards in the northern parts. But the difference in the latitude between the northern and the southern parts, and, consequently, the difference in the velocity of rotation, is so slight that the currents resulting from westward pressure may, not improbably, be masked by the action of other forces; and the depression of the water at its eastern end may, therefore, not improbably, be the only clearly apparent effect resulting from the action of westward pressure in that sea. The pressure against the Isthmus of Suez in the Red Sea is not the full force of equatorial pressure; nor, on the other hand, is the pressure from the coast in the Mediterranean; and yet the difference in the level of the water about the isthmus, as recorded by Major Rennell, shows the effects of that pressure.

188. And further: as we have seen that, according to our theory, westward pressure tends to cause the level of the Red Sea to be higher than that of the eastern end of the Mediterranean,—the former

being raised, and the latter depressed by the action of that force;—so also, in accordance with that theory, must the action of westward pressure tend to raise the level of the waters of the Caribbean Sea and Gulf of Mexico above the level of the adjacent parts of the Pacific Ocean. For the full force of westward pressure in the North Atlantic is tending to heap up the waters of the Atlantic against the eastern side of the Isthmus of Panama: whereas the westward pressure of the Pacific tends to carry away the water, and depress the level of the Ocean on the western side of the Isthmus of Panama.

Now, that the waters of the Caribbean Sea and Gulf of Mexico are actually raised above the level of the central parts of the Atlantic, is a very general opinion. This difference in level being attributed to the action of the trade-winds; and, according to our theory, being the result of the westward pressure of the ocean itself, the trade-winds contributing towards it, but being comparatively a very trivial cause.

If the relative level of the waters of the Pacific and Atlantic Oceans adjacent to the Isthmus of Panama be determined by the action of evaporation, it appears reasonable to expect that, all other circumstances being similar, the Atlantic waters should be the lower, because not only is the heat of the Caribbean Sea and Gulf of Mexico greater than that of the adjacent parts of the Pacific; but also, from those seas

being more confined, any loss caused by evaporation would be less readily replaced than that carried off by evaporation from the open waters of the Pacific.

If, however, by the action of evaporation the level of the waters of the Gulf of Mexico be depressed below that of the adjacent parts of the Pacific, and be, notwithstanding, higher than the general level of the Atlantic ; then must the general level of the Atlantic be lower than those parts of the Pacific.

If, then, the winds and evaporation be regarded as the causes which determine such differences of level as are at present under consideration; and, if cause cannot be shown why, through the agency of the winds and evaporation those parts of the Pacific adjacent to the Isthmus of Panama should stand at a higher level than the rest of the Pacific Ocean; then must it be contended that the level of the Pacific is altogether higher than that of the North Atlantic; as a cause for which the winds and evaporation are obviously inadequate. In fact, the winds and evaporation must be discarded as comparatively trivial forces, and altogether inadequate to cause any important difference in level between those parts of the Pacific and Atlantic adjacent to the Isthmus of Panama.

We have said that westward pressure tends, about the Isthmus of Panama, to raise the level of the Atlantic and to depress that of the Pacific. And

that the influence of westward pressure in raising a current tide on the eastern side of the Isthmus, and depressing the water on the western side, must, according to our theory, immensely preponderate over any possible effects of evaporation which cannot do more than cause a trivial increase or decrease in the difference of level which would result from the sole action of westward pressure. Nor does it appear to us possible that among all the forces hitherto known and recognised as acting upon the ocean and atmosphere, there can be any counteracting influence sufficiently powerful to prevent the action of westward pressure from actually causing the level of the Atlantic to be higher than that of the Pacific about the Isthmus of Panama.

189. Notwithstanding this, we find it stated in Lippincott's Geographical Dictionary that, 'the mean level of the Pacific, as ascertained by measurements taken in the Bay of Panama and the Gulf of Mexico, is supposed to be 3½ feet above that of the Atlantic.' And when we consider that, according to the arguments contained in vol. i., the magnetic needle, when placed at the south magnetic pole, pointing right away into space, marks the point in space towards which the earth is moving; and the Pacific shore of the Isthmus of Panama, lying almost at right angles to the direction of that motion, receives the full force of the northward pressure caused in the South Pacific by that motion: then the fact above mentioned

corroborates the evidence deduced independently from other facts; for it simply shows that the northward pressure, resulting from the motion of the solar system through space, is greater than the westward pressure resulting from the axial rotation of the earth, even in the equatorial regions.

If the solar system be moving in the direction of the south pole, then the average level of the South Pacific must, according to sections 129 and 130, vol. i., be higher than that of the North Atlantic; inasmuch as the attraction tide in the southern hemisphere is higher than the vis inertiæ tide in the northern hemisphere. And also, the force of vis inertiæ acting northwards through the vast mass of water which forms the South Pacific must tend to cause a heaping up of the water on the Pacific coast of the Isthmus of Panama. And if the level of the water on the Pacific side of the Isthmus be higher than that of the water on the Atlantic side, then it follows that the northward pressure in the South Pacific, which tends to heap up the water against the Isthmus of Panama, is greater than the westward pressure which tends to depress the level of that part of the ocean.

As far as this difference in level about the shores of the isthmus is concerned: if a difference of level be alone considered apart from all other considerations, then it may be urged that a force of attraction drawing in the direction of the North Pole might, by

drawing northwards, raise the Pacific level above that of the Atlantic. But, if such were the case, then that same force should, by drawing the water away from the Atlantic shore of the isthmus, depress the level of the Caribbean Sea below the general level of the Atlantic. It would be completely at variance with that which we suggested, in vol. i., as the cause of the greater accumulation of land in the northern than in the southern hemisphere. And it would leave the observed oscillations of the barometer unexplained. For, as stated in our preceding chapter, in the southern hemisphere the barometer is lower when that hemisphere is in advance in the orbital motion of the earth than when the northern hemisphere is in advance: and also in the northern hemisphere the barometer is lower when that hemisphere is in advance, than when the southern hemisphere is in advance. And, since the average height of the barometer is lower in the southern hemisphere than in the northern hemisphere, therefore the evidence deduced from the barometer tends to show that in the motion of the solar system through space the southern hemisphere of the earth is in advance.

The evidence deduced from these various sources harmoniously converges towards the demonstration of a motion of the earth in the direction of the south pole. The denial of that motion throws all into discord and confusion. And even though the evidence

of the ocean currents, of the tides, of the winds, of the barometer, of the magnetic needle, or of the configuration of land and water, may bear other interpretations when considered alone, we are compelled to accept the weight of their evidence as irresistible when thus combining in harmonious concord.

CHAPTER VIII.

190. Expecting to find in the movements of the outer crust of the earth and the contortions of its strata, signs of the combined action of evanescence and gravitation, we, in the third chapter of our first volume, digressed from our investigation of the position and movements of the ocean and the atmosphere and entered the realms of geology. This we have termed a digression; but in fact, a consideration of the forces which determine the configuration of the outer crust of the earth, is absolutely requisite in the course of an investigation of the forces which determine the position of the ocean.

We came to the conclusion that the contortions of the outer crust of the earth are such as might naturally be expected from the action of the force of lateral pressure which should result, from the gradually decreasing size of the globe, under the influence of evanescence and gravitation.

It will be observed that our object then was, to ascertain whether or not the action of evanescence and gravitation were apparent in the actual condition of the outer crust of the earth. And, so far

from asserting that all the phenomena presented by earth's surface are the result of lateral pressure, we stated that the outer crust of the earth must be under the dominion of the same forces as are the ocean and the atmosphere. If, then, the interior of the earth be in a state of liquid incandescence, that liquid mass must heave and throb with tidal movements analogous to those of the ocean and the atmosphere. It must stream around; and sway to and fro against the inner surface of earth's hardened crust, with an action more or less similar to that of the ocean and atmosphere against the outer surface of that crust. The force of its pressure against any given part of earth's crust will be subject to diurnal and annual variations in accordance with the changes of its position in relation to the various tidal forces.

In the sketch of the action of lateral pressure, contained in the third chapter of our first volume, we supposed that we were advancing what was in a great measure a new theory of the causes of the undulations of earth's surface. It appears, however, from the tenth edition of Sir Charles Lyell's 'Principles of Geology,' the first volume of which has just issued from the press, that there is no novelty in those views; but that they originated with M. Elie de Beaumont, and have for many years been elaborately supported by him. We therefore fall back on the authority of M. Elie de Beaumont in maintaining that the contortions of the outer crust of the earth

are such as should result under our theory of the action of the forces of evanescence and gravitation. Those views of M. Elie de Beaumont, are corroborated by the theory of magnetic action advanced in our preceding volume. But, before dwelling on the similarity of the conclusions arrived at by these widely different lines of reasoning, let us briefly consider the movements and configuration of the outer crust of the earth which should result from the action of the forces described in our preceding volume.

Of those forces, the great predominating force of gravitation may be termed a static force. This static force is acted upon by a dynamic force which causes axial rotation; and thereby induces the action of centrifugal force: by another dynamic force which causes motion through space; and thereby induces the magnetic action described in section 143: and by a third dynamic force causing a transmutation of the material into the immaterial, and thereby inducing a dynamic action of the otherwise static force of gravitation, from which results the lateral pressure just mentioned. As to whether the first and second of these dynamic forces be simply dynamic actions of gravitation caused by the action of the third dynamic force, which we have termed evanescence, is a question which does not concern us at present. For our present object is, without attempting to decide upon

the abstract nature of any of these forces, to consider what configuration their combined action would give to a globe more or less resembling the earth, supposing the action of each of these forces to be such as described in volume i.

191. For the sake of illustrating the action of these forces, let us suppose a globe in space: of which, let the outer covering be air; beneath that air an unbroken expanse of water; beneath that water a hardening, but still more or less pliant, surface of land; and beneath this land, or outer crust of the globe, a fluid incandescent mass homogeneous with the materials whose solidification has formed the outer crust, or land.

Under the sole action of its own force of gravitation that globe would naturally tend to preserve its form as a perfect sphere.

If, however, in that globe there be induced a motion of rotation round an axis passing through its centre, then by that motion a centrifugal force is created, acting from the axis towards those parts of the surface which, being most remote from the axis, rotate with the greatest velocity. On the surface of the globe, this force would act from the poles of the axis towards the equator. And, supposing the land or outer crust of the globe to be sufficiently pliant, then the liquid mass within it would bulge it out all round the equator and draw it inwards at each of the poles; thereby causing its equatorial to

be greater than its axial diameter. The action of this force would not tend to cause any difference between the hemispheres lying on either side of the equator; but, as far as its action is concerned, those hemispheres would be equal and their configuration similar.

192. Let there, however, be induced, besides this axial rotation, a motion onwards through space in the direction of either of the poles—say the south pole. And, in the same manner as that in which the centrifugal force, just above described, is concomitant with axial rotation, let the magnetic action, described on page 69 of volume i., be concomitant with that motion through space. Then in the central line of motion the surface of the earth is drawn in the direction of that motion with greater force than those parts of the surface remote from that central line of motion, so that these latter parts have a relative tendency to fall back in the opposite direction: and by this action, therefore, the surface of the earth about the north pole is drawn inwards; that about the south pole bulged outwards; that in the temperate zone of the southern hemisphere pressed inwards; and that in the temperate zone of the northern hemisphere bulged outwards.

193. The independent action of each one of these forces is illustrated by the curve lines in the design on the cover of this volume. In that design, the sphere shows the action of gravitation; the oblate

spheroid the action of centrifugal force, resulting from axial rotation; and the cardioid the action of magnetic force, resulting from motion through space. And under the combined action of these forces the configuration of the earth would, therefore, be such, that if on the surface of the earth there lay water sufficient to cover one half of earth's surface; that water lying in each of the depressions, and leaving the protuberances dry land: then the surface of the earth would be divided into the following alternate zones of land and water. Namely: land about the south pole; a vast expanse of water throughout the temperate regions of the southern hemisphere; a zone of dry land in the equatorial regions; a narrow zone of water north of the equator; a zone of dry land throughout the temperate regions of the northern hemisphere; and a district of water about the north pole.

The land in the temperate zone of the northern hemisphere, and that about the south pole, would be raised by the action of the magnetic force concomitant with motion through space: and the land in the equatorial zone would be raised by the action of the centrifugal force concomitant with axial rotation. The relative positions of land and water resulting from the action of the forces just described, strikingly correspond with the actual relative positions of land and water in each hemisphere; excepting that the

zones instead of being continuous are intersected by undulations running north and south.

194. We have, however, as yet applied only the dynamic forces of axial rotation, and onward motion through space. Let us consider the action of the third dynamic force, or evanescence. The tendency to contraction, resulting from this evanescence, induces lateral pressure throughout the outer crust of the earth; and if that outer crust have not sufficient strength to resist the action of gravitation; it must, if sufficiently pliant, have a tendency to undulate all over; or, if not sufficiently pliant to undulate, its tendency must then be to shiver to fragments. Let us consider in what manner this tendency to undulate or to fracture can take effect.

195. We have seen that the vis inertiæ force resulting from axial rotation, and that resulting from orbital motion, both act westwards in any given part of the surface of the earth when that part of the surface is turned from the sun, but as soon as that part of the surface reaches the point of sunrise, then the conjoint action of those forces ceases; the orbital force of vis inertiæ abruptly turns eastwards, and acts in opposition to the force of vis inertiæ resulting from axial rotation. Thus, then, the alternate conjunction and opposition of these forces of vis inertiæ would control the undulating action of lateral pressure; and cause those undulations to take the form of a series of ocean waves sweeping westwards. These,

then, appear to be the forces which have determined the peculiarities of conformation, which have been so clearly pointed out by the late Rear-Admiral Fitzroy in the following passage, which we extract from the 'Weather Book.' On page 121 of that work Admiral Fitzroy draws attention

"to a very remarkable geologic conformation, common to a great part of our world approachable by sea, though not so much to the far interior of extensive continents: namely, gradual slope up from east towards west, and comparatively precipitous steeps, from summits, westward. Norway, Europe generally, Africa, with its outlying islands, both Americas, the Galapagos, the (elevated) Polynesian islands, the ranges of Australia, China, and Asiatic sea-coasts generally, when viewed extensively in profile from south to north, have the wedge-like outline that is familiar to Englishmen in the Bill of Portland. To the physical philosopher and the geologist we must turn for reasoning on this striking peculiarity—one that the writer has often noticed and considered with extreme interest. His attention was first drawn to it, by seeing the Galapagos group, from a distance, appearing like several 'Bills of Portland,' all exactly similar in their profile outline when many miles distant. Since that time (1836), many opportunities have occurred for enquiries and careful comparisons, of which the result is a belief, that excepting those greater east and west ranges of mountains embodied within continents, or continental islands (such as Australia and Borneo), the general average direction of ranges or chains of mountains is nearly meridional, and their section approaches that of a wedge (pointing eastward).

"This wedge-like shape is common to every little sand-ridge, every shifting shingle bank, formed along shore by wave or tidal action. It is also that of sand-ridges on

a plain, drifted by wind alone, and it is the form of snow-drifts—the point of the wedge being towards the source of action. Whether water, or wind, or both, acting *continuously*, have been agents in these conformations; whether, in contracting or expanding, the earth's surface or crust has had a tendency to scale-like fracturing, must be left to the consideration of competent judges."

These conformations, observed by Admiral Fitzroy, appear clearly to coincide with such as might naturally be expected to result from the alternate conjunction and opposition of the vis inertiæ forces acting in combination with the undulating tendency of lateral pressure.

196. We observed in chapter iii. that the centrifugal force resulting from axial rotation might be expected in some measure to neutralise the undulating action of lateral pressure acting north and south, so that the greatest apparent effects of undulating force should result from the pressure acting east and west. This would not, however, account for any one of the meridional undulations being greater than any other. But, as far as the forces which we have thus far brought into play are concerned, all the meridional undulations on our hypothetical globe would be equal and similar. There are, however, on the surface of the earth two meridional undulations immensely greater than all others, the crests of which form respectively the Old and New Worlds; and the depressions between them con-

taining respectively the Atlantic and Pacific Oceans. And such a meridional division of land and water, we suggested in volume i., would naturally result from a change of the earth's axial rotation, from any axis to a new axis at right angles to the position of the old axis. And, in fact, if in this sketch we have correctly described the action of the forces which we have brought into play on our hypothetical globe, then it would appear from the actual conformation of the outer crust of the earth, that such a change of the axis of rotation as we have above mentioned, has occurred not once only, but many times. In such case the wave-like conformations observed by Admiral Fitzroy must have been formed since the occurrence of the last change of axis: these comparatively modern undulations intersecting older similar undulations, and obliterating, to a greater or lesser extent, the traces of their original conformation.

Let us consider how such a change of axis as that just mentioned would affect the configuration of the hypothetical globe which we have been describing. By such a change the position of the poles of the new axis would be in opposite points of the old equator: and the new equator would intersect the old at points ninety degrees from each of those poles. The equatorial diameter between those points would then be greater than that at right angles to it; for this latter would be the line of the former axis of rotation. And centrifugal force, carrying the water to

the equatorial regions would cause it to accumulate in two great oceans whose central points would be over the poles of the former axis : and those oceans would be separated meridionally by a belt of land lying along the line of the former equator. Then, supposing the outer crust of the earth to be sufficiently pliant, the configuration which the action of the forces before described would tend to restore would be modified by meridional undulations. For those undulations which, before the change of axis, formed the zones of land and water running parallel to the old equator, would after that change of axis lie meridionally, or at right angles to the new equator.

In this new position, under the action of the forces which caused the former configuration, a portion of the former equatorial regions would be sustained to form the new Antarctic continent, and the opposite part depressed to form the basin of the Arctic ocean. And also; from the central parts of one of the great oceans, there would gradually be upraised the crest of the undulation which had formed the old Antarctic continent; and about the central parts of the other of the great oceans there would gradually be upraised the crest of the undulation which had encircled the former Arctic ocean. The undulating tendency of lateral pressure, acted upon by the vis inertiæ forces resulting from axial rotation and orbital motion, would then tend to raise a new series of meridional undulations intersecting, at right

angles, those previously raised by the action of those same forces.

If a portion of Brazil be supposed to have formed at one time an Antarctic continent, then the actual configuration of land and water on the surface of the earth presents a striking resemblance with that which would naturally result from the action of the forces which we have described. But if we have correctly described the action of those forces, then some previous changes of the axis of rotation would be requisite in order to account for the absence of land in the central parts of the Pacific, opposite the equatorial regions of Africa.

The investigation of this point offers a problem, intricate and interesting, but unsuited to the purpose of this chapter, which is simply to illustrate the universality of the action of the forces which determine the position and movements of the ocean and atmosphere. In these fluids the force of evanescence could leave no visible trace of its action; but if such force there be, then must the action of that force be recorded in the hardened crust of the earth. And, if our arguments be not erroneous, then does the actual configuration of earth's crust show the action of the forces in the play in the ocean and atmosphere, and confirm that southward motion of the earth which we in the first instance deduced from the observed course of the ocean currents.

CHAPTER IX.

197. That motion of the earth in the direction of the south pole, which appears to be demonstrated by the phenomena just mentioned, we have, in the course of our arguments, treated as if resulting from the motion of the solar system. For we have remarked, in sections 144 and 145, that the effects of motion as shown by tides, currents, and winds, will be the same whether those effects result simply from a motion of the solar system in the direction of the south pole, or be the average result of a motion of the solar system in the direction of the north pole combined with a motion of a more extensive system, with a greater velocity in the opposite direction.

That is to say, as far as the arguments which we have hitherto adduced are concerned, those effects might either result from a motion of the solar system by which the earth is moved together with that system; sweeping along among the stars which compose the visible part of the universe, and so changing its position among those stars; or, they might be the result of a motion of the whole stellar system, in which the earth, the sun, and the stars,

equally partake as particles of that system; the motion demonstrated in the direction of the south pole being, in such case, a majestic movement in which the whole visible universe is plunging onwards through space.

And, since astronomical observations appear to have shown that the solar system has a motion among the stars by which it is carried along in the direction of the northern hemisphere, we are, if those observations be reliable, compelled to the conclusion that in the same manner as that in which, when the moon is inside the earth's orbit, the lesser velocity of its orbital motion round the earth is swallowed up in the greater velocity of the orbital motion in which, together with the earth, it is carried round the sun; so also, in a similar manner, must the velocity of the motion in which the solar system is carried northwards among the stars, be swallowed up in the greater velocity of a motion in which, together with the stars, it is plunging southwards.

The winds, as they sweep earth's surface;—the waters of the ocean, as they ebb and flow;—the trembling needle as it variously declines eastwards or westwards, or inclines from earth to heaven or heaven to earth;—the liquid silver in the Torricellian tube, as it variously oscillates with wave-like motion;—the configuration of the earth itself;—these all with one voice tell us of earth's career southwards. And, through the Galilean lenses, faint radiations from the